I. *A Propoſal of a Method for finding the* Longitude *at* Sea *within a Degree, or twenty Leagues. By Dr.* Edmund Halley, Aſtr. Reg. *Vice-Preſident of the* Royal Society. *With an Account of the Progreſs he hath made therein, by a continued Series of accurate* Obſervations *of the* Moon, *taken by himſelf at the* Royal Obſervatory *at* Greenwich.

IT is now above twenty Years ſince I added an *Appendix* to the ſecond Edition of *Mr. Street*'s *Caroline Tables*, containing a Set of Obſervations I had made in the Years 1683 and 1684, for aſcertaining the Moon's Motion; and giving a *Specimen* of what I thought, at that Time, might be the only practicable Method of attaining the *Longitude* at *Sea*. What I printed ſo long ago, is as follows:

" The Advantages of the Art of finding the " Longitude at Sea, are too evident to need any Ar- " guments to prove them. And having by my own " Experience found the Impracticability of all other " Methods propoſed for that Purpoſe, but that deri- " ved from a perfect Knowledge of the *Moon's Moti-* " *on*; I was ambitious, if poſſible, to overcome the " Difficulties that attend the Diſcovery thereof.

" And firſt, I had found it only needed a little " Practice to be able to manage a five or ſix Foot Te- " leſcope, capable of ſhewing the Appulſes or Occulta- " tions of the *Fix'd Stars* by the *Moon*, on Ship- " board, in moderate Weather; eſpecially in the Firſt

" and Laſt *Quarters* of the *Moon*'s *Age*, when her " weaker Light does not ſo much efface that of the " *Stars*. Whereas the Eclipſes of the *Satellites* of " *Jupiter*, how proper ſoever for *Geographical* " Purpoſes, were abſolutely unfit at Sea, as requi- " ring Teleſcopes of a greater Length than can well " be directed in the rolling Motion of a Ship in " the Ocean.

" Now the Motion of the Moon being ſo ſwift, " as to afford us ſcarce ever leſs than two Minutes for " each Degree of Longitude, and ſometimes two " and a half; it is evident, that were we able per- " fectly to predict the true Time of the Appulſe or " Occultation of a Fix'd Star, in any known Meridi- " an, we might, by comparing therewith the Time ob- " ſerved on Board a Ship at Sea, conclude ſafely how " much the Ship is to the Eaſtward or Weſtward of the " *Meridian* of our *Calculus*.

" But after much Examination, and carefully col- " lating the *Caroline Tables of Mr. T. Street* (though " generally better than thoſe that went before him) " as likewiſe thoſe of *Tycho*, *Kepler*, *Bullialdus*, and " our *Horrox*, with many accurate Obſervations of " the *Moon*, carefully made on Land; it does not ap- " pear that any of theſe *Tables* do repreſent the Moti- " ons with the Certainty required; and though many " times the Agreement ſeems ſurprizing, when the " Errors of the ſeveral *Equations* compenſate one ano- " ther; yet in thoſe Parts of the *Orb* where they " all fall the ſame Way, the Fault is intolerable, and " the Reſult many times not to be depended on, to " more than one hundred Leagues; that is to ſay, it is " wholly inſufficient.

" Yet

" Yet ſtill this Fault is *Artificis*, not *Artis*: For " obſerving the *Period* of the *Lunar Inequalities*, " which is performed in eighteen Years and eleven " Days, or two hundred and twenty-three *Lunati-* " *ons*; it is found that the Returns of the Eclipſes, " and other Phænomena of the Moon's Motion, are " very regularly performed; ſo that whatever Error " you found in a former Period, the ſame is again re- " peated in a ſecond, under the like Circumſtances of " the ſame Diſtance of the Moon from the Sun and " *Apogæon*.

" Thus, from the Obſervation made of the E- " cliſpe of the Sun, which was *June* 22, 1666, in " the Morning, ſeen at *London* and *Dantzick*, I " was enabled to predict, with great Certainty, that " other, which I obſerved *July* 2, 1684, by al- " lowing the ſame Error I found in the *Calculus* " of the former. And the like with equal Certainty " will do, in the Caſes *extra Syzygias*, when the " Mean and Synodical Anomolies are nearly the " ſame, about the ſame time of the Year.

" Being thus aſſured, from the Certainty of theſe " Revolutions, that all the intermediate Errors of our " *Tables* were not uncertain Wandrings, but regular " Faults of the *Theories*; I next thought how I might " beſt be informed of the Quantity and Places of theſe " Defects: That being apprized how much, and which " Way my Numbers erred, I might apply the Dif- " ference, ſo as at all times to repreſent the true Mo- " tion of the *Moon*. Nor was there any other Way, " but from the Heavens themſelves, to derive this " Correction, by a ſedulous and continued *Series*

" of *Obſervations*, to be collated with the *Calculus*, " and the Errors noted in an *Abacus*: From whence, " at all Times, under the like Situation of the *Sun* " and *Moon*, I might take out the Correction to be " allowed.

" And having by me the *Sextant* I made to " obſerve the Southern *Stars* at *St. Helena*, in " the Year 1677, I fixed it for this Purpoſe; re- " ſolving to have continued to obſerve, till I had " filled my *Abacus*, ſo as it might have the Effect " of exact *Lunar Tables*, capable to ſerve at Sea, " for finding the *Longitude* with the deſired *Cer-* " *tainty*.

" With this Deſign, I applied the Leiſure I had " procured myſelf about the Year 1683, to obſerve di- " ligently, as often as the Heavens would permit, the " true Place of the Moon, eſpecially as to Longitude; " and in the Space of about ſixteen Months I had " gotten near two hundred ſeveral Days Obſervations, " moſt of which I collated with the *Horroxian* " *Theory* (whoſe *Calculus* is ſomething more com- " pendious than that of Mr. *Street*) and having pla- " ced the Errors in an *Abacus*, I perceived how re- " gular the Irregularities were, and that where the " Moon had been exactly obſerved formerly, at the " Diſtance of one or more Periods of two hundred " twenty-three Months, I could even predict the " Error of the *Tables*, with a Certainty not much " inferior to that of the Obſervations themſelves. " But this Deſign of mine was ſoon interrupted by " unforeſeen domeſtick Occaſions, which obliged me " to poſtpone all other Conſiderations to that of the

" De-

" Defence of my Patrimony: And, ſince then, my " frequent Avocations have not permitted me to re- " aſſume theſe Thoughts.

" In the mean time I have taken Care to preſent my " Obſervations, ſuch as they are, to the Publick, in " order to preſerve them; aſſuring, that as on the " one Hand they were made with a very ſufficient *In-* " *ſtrument*, with all the Care and Diligence requiſite; " ſo in the remote Voyages I have ſince taken to aſ- " certain the *Magnetick Variations*, they have been " of ſignal Uſe to me, in determining the *Longitude* " of my *Ship*, as often as I could get Sight of a " near *Tranſite* of the *Moon* by a known *Fix'd* " *Star*: And thereby I have frequently corrected " my *Journal* from thoſe Errors which are unavoid- " able in long Sea-Reckonings.

" If therefore you happen at *Sea* to obſerve nice- " ly the Time of an *Occultation* or cloſe *Applica-* " *tion* of a *Star* to the *Moon*; and can find a cor- " reſpondent Obſervation, about the ſame mean *Ano-* " *maly* and Diſtance of the *Moon* from the *Sun* (either " among theſe of mine, or in any other Collection " of Obſervations accurately made) eſpecially near " the ſame Time of the Year; and, above all, after " the aforeſaid *Period* of eighteen Years and eleven " Days, you may, without ſenſible Error, from " thence pronounce in what *Meridian* your *Ship* is; " taking Care in ſo operoſe a Calculation, to commit " no Miſtake; and, notwithſtanding the Direction " the Moon gives you, not confiding ſo much there- " in as to omit any of the uſual Precautions to preſerve " a Ship when ſhe approaches the Land.

" I had

" I had intended to inſiſt more largely upon this " Method of obtaining the *Moon*'s *Place*, and, by " Conſequence, the *Longitude* at *Sea*, but that I " find, that it requires a juſt Treatiſe, too long to " be here ſubjoined: And, more eſpecially, that " the great Sir *Iſaac Newton* (to whom no Ma- " thematical Difficulty is inſuperable) has been " pleaſed to give us a *True* and *Phyſical Theory* of " the *Moon*'s Motions, whereby the Defects of all " former *Tables* are ſo far amended, that it is hoped " the Error may ſcarce ever exceed three Minutes of " Motion, or ſo little in *Longitude*; that, perhaps, " it may be thought a ſufficient Exactneſs for all the " Uſes of *Navigation*. If therefore what is here offer- " ed find a kind Acceptance from thoſe that it chiefly " concerns, I ſhall be encouraged to proceed on a " Work I have long meditated, to improve the above- " mentioned *Period*, as to the abbreviating the Com- " putation of *Eclipſes*, and, in general, to facilitate " the too laborious *Calculation* of the *Moon*'s *Place* " *extra Syzygias*.

Not long after her late Majeſty Queen *Anne* was pleaſed to beſtow upon the Publick, an Edition of the much greater, and moſt valuable Part of Mr. *Flamſteed*'s Obſervations; by Help of which the great Sir *Iſaac Newton* had formed his curious Theory of the *Moon*, a firſt Sketch of which was inſerted by Dr. *David Gregory* in his *Aſtronomiæ Phyſicæ & Geometricæ Elementa*, publiſhed at *Oxford*, 1702; and again, in the ſecond Edition of Sir *Iſaac*'s *Principia*, which came out in 1713, we have the ſame

ſame reviſed and amended by himſelf, to that Degree of Exactneſs, that the Faults of the *Computus* formed therefrom rarely exceed a quarter Part of what is found in the beſt *Lunar Tables* before that Time extant.

Being thus provided with proper Materials, *viz.* a large Set of Obſervations, and a *Theory* of the *Motions* ſo very near the Truth, I reſumed my former Deſign of filling up my *Abacus* or *Synopſis* of the Defects of this *Lunar Theory*, and made Tables to expedite the *Calculus* according thereto, and compared the Numbers thereof with many of the moſt certain of Mr. *Flamſteed*'s Places obſerved. By this it was evident that Sir *Iſaac* had ſpared no Part of that Sagacity and Induſtry ſo peculiar to himſelf, in ſettling the *Epoches*, and other *Elements* of the *Lunar Aſtronomy*, the Reſult many times, for whole Months together, rarely differing two Minutes of Motion from the Obſervations themſelves; nor is it unlikely but good Part of that Difference may have been the Fault of the Obſerver. And where the Errors were found greater, it was in thoſe Parts of the *Lunar Orb* where Mr. *Flamſteed* had very rarely given himſelf the Trouble of obſerving; *viz.* in the third and fourth Quarter of the *Moon*'s Age, where ſometimes theſe Differences would amount to at leaſt five Minutes.

Mr. *Flamſteed* was long enough poſſeſſed of the *Royal Obſervatory* to have had a continued Series of Obſervations for more than two *Periods* of eighteen Years; by which he had it in his Power to have done all that could be expected from Obſervation, towards

towards diſcovering the *Law* of the *Lunar Motions*. But he contented himſelf with ſparſe Obſervations, leaving wide Gaps between, ſo as to omit frequently whole Months together; and in one Caſe the whole Year 1716. So that notwithſtanding what he has left us muſt be acknowledged more than equal to all that was done before him, both as to the Number and Accuracy of his Accounts; yet for want of an uninterrupted Succeſſion of them, they are not capable of diſcovering, in the ſeveral Situations of the *Lunar Orbit*, what Corrections are neceſſary to be allowed, to ſupply the Deficiencies of our *Computus*.

On Mr. *Flamſteed*'s Deceaſe, about the Beginning of the Year 1720, his late Majeſty King *George* I. was graciouſly pleaſed to beſtow upon me the agreeable Poſt of his *Aſtronomical Obſerver*, expreſly commanding me *to apply my ſelf with the utmoſt Care and Diligence to the rectifying the Tables of the Motions of the Heavens, and the Places of the Fix'd Stars, in order to find out the ſo much deſired Longitude at Sea, for the perfecting the Art of Navigation.* Theſe are the Words of my *Commiſſion*; and here I might have thought myſelf in a Condition to put in Execution my long projected Deſign of compleating my *Abacus*, or Table of the Defects of our *Lunar Numbers*; but on taking Poſſeſſion, I found the *Obſervatory* wholly unprovided of *Inſtruments*, and indeed of every thing elſe that was moveable, which poſtponed my Endeavours till ſuch Time as I could furniſh myſelf with an *Apparatus* capable of the Exactneſs requiſite. And this was the more grievous to me, on account of my advanced Age,

Age, being then in my ſixty-fourth Year, which put me paſt all Hopes of ever living to ſee a compleat *Period* of eighteen Years Obſervation.

But, Thanks to GOD, he has been pleaſed hitherto to afford me ſufficient Health and Vigour to execute my Office in all its Parts with my own Hands and Eyes, without any Aſſiſtance or Interruption, during one whole *Period* of the *Moon*'s *Apogee*; which *Period* is performed in ſomewhat leſs than nine Years. In this Time I have been able to obſerve the *Right Aſcenſion* of the *Moon* at her *Tranſit* over the *Meridian*, near fifteen hundred times (and with an Exactneſs, I am bold to ſay, preferable to any thing done before) a Number not leſs than thoſe of the noble *Tycho Brahe*, *Hevelius* and *Flamſteed*, taken in one Sum, there being near four of my Lunar Obſervations for each Degree of the Zodiack, as alſo for each Degree of the *Argumentum annuum*, or Diſtance of the *Sun* from the *Moon*'s *Apogee*. And that theſe might be duly applied to rectify the Defects of our *Computations*, I have myſelf compared with the aforementioned Tables, made according to Sir *Iſaac*'s Principles, not only my own Obſervations, but alſo above eight hundred of Mr. *Flamſteed*'s.

This *Compariſon* of my own *Obſervations* (from the Time I eſteem them compleat) with the *Computus* by the ſaid Tables, being now continued for above nine Years, I deſign ſpeedily to communicate it to the Publick, together with the Tables themſelves, which have been printed, and ſhould long ſince have been publiſhed, had not my Poſt at *Greenwich* given me an Opportunity to examine, with proper Nicety, in

what Parts of the *Lunar Orb*, and how much, our Numbers erred. So uſeful an Addition as this, it is hoped may fully anſwer the long delayed Expectation ſome Perſons may have had of ſeeing the ſaid Tables ſooner. By Means thereof, thoſe that are qualified may, if they pleaſe, examine by their own Obſervation the Truth of what is here aſſerted.

Comparing likewiſe many of the moſt accurate of Mr. *Flamſteed*, made eighteen or thirty-ſix Years before (that is one or two *Periods* before mine) with thoſe of mine which tallied with them, I had the Satisfaction to find that what I had propoſed in 1710 was fully verified; and that the Errors of the *Calculus* in 1690 and 1708, for Example, differed inſenſibly from what I found in the like Situation of the Sun and Apogee, in the Year 1726. The great Agreement of the *Theory* with the *Heavens* compenſating the Differences that might otherwiſe ariſe from the Incommenſurability and Excentricity of the Motions of the Sun, Moon and Apogee.

Encouraged by this Event, I next examined what Differences might ariſe from the Period of nine Years wanting nine Days, in which Time there are performed very nearly one hundred and eleven *Lunations*, or Returns of the *Moon* to the *Sun*; but the Return of the *Sun* to the *Apogee* in that Time differing above four times as much from an exact Revolution as in the Period of eighteen Years, I could not expect the like Agreement in that. However, having now entered upon the tenth Year, I compared what I had obſerved in the Years 1721 and 1722, with my late Obſervations of 1730 and 1731, and have rarely found a Difference of more

more than one ſingle Minute of Motion (Part of which may probably ariſe from the ſmall Uncertainty that always attends Aſtronomical Obſervation) but moſt commonly this Difference was wholly inſenſible; ſo that by the Help of what I obſerved in 1722, I preſume I am able to compute the true Place of the Moon with Certainty, within the Compaſs of two Minutes of her Motion, during this preſent Year 1731, and ſo for the future. This is the Exactneſs requiſite to determine the Longitude at Sea to twenty Leagues under the Equator, and to leſs than fifteen Leagues in the *Britiſh* Channel.

It remains therefore to conſider after what Manner Obſervations of the Moon may be made at Sea with the ſame Degree of Exactneſs: But ſince our worthy Vice-Preſident *John Hadley*, Eſq; (to whom we are highly obliged for his having perfected and brought into common Uſe the *Reflecting Teleſcope*) has been pleaſed to communicate his moſt ingenious Invention of an Inſtrument for taking the Angles with great Certainty by Reflection, (*Vide Tranſact.* N° 420.) it is more than probable that the ſame may be applied to taking Angles at Sea with the deſired Accuracy.

II. *An Account of the* Contrayerva, *by Mr.* William Houſtoun, *Surgeon in the Service of the Honourable* South-Sea *Company.*

CONTRAYERVA is a *Spaniſh* Word, ſignifying as much as *Herba contra* [*Venena*] or an Herb againſt Poiſons. And as there are in all Countries